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Plant-based extraction of phenolic compounds for anti-melanogenic facial mask development in nutricosmetic industry: A review

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Plant-based extract is an important source of bioactive compounds, mainly secondary metabolites including phenolic compounds responsible for various functional bioactivities including antioxidant, anti-melanogenic, anti-inflammatory, and anticancer. The application of plant-based extract is commonly found in the nutraceutical and pharmaceutical sectors. Nowadays, the demand on plant-based extract has expanded to cosmeceutical industry. The consumers demand for natural and safe plant extract for human health has dramatically increased. Moreover, edible plant extract is safe and natural for human consumption. This perspective triggers the emerging of food science and technology incorporation with cosmeceutical which known as nutricosmetics. Therefore, this review discussed on plant-based extraction techniques in extracting phenolic compounds including classic and modern extraction. The applications of plant-based extract in nutricosmetics focussed on development of topical facial mask with health benefit are further discussed. The anti-melanogenic properties as the common consumer target to combat skin hyperpigmentation were highlighted. Research revolution of selected ingredient in applying into nutricosmetic products are explained in this review. The challenge and future prospective for the development topical facial mask for nutricosmetic are discussed. The plant-based activated carbon may be a potential research area to be explored in future study. Therefore, this review is important for researcher as first exposure on phenolic compounds for further application in nutricosmetics industry.

Keywords: nutricosmetic, phenolic, plant extract, skin care, anti-melanogenic

INTRODUCTION

Plant-based extract contained valuable bioactive compounds which showed the potential in various uses. The growing interest of natural resources from plant-based extract has becoming an important ingredient for product development in food, nutraceutical, cosmeceutical, and pharmaceutical sectors. In traditional treatment, plant-based extract is widely used to treat colds, nausea, headache, and skin disease (Nyagumbo et al. 2022). The plant-based extract is also useful in wound healing, skin ulcer, and rheumatic pains (Jena et al. 2020). In modern applications, plant-based extract is commonly used as an active ingredient in topical and edible products in the market. The plant sources are collected, dried, grind and extracted before incorporating the extract in product formulations. Hence, the determination of stability and shelf life of plant-based extract becoming an important consideration in developing high-quality products. Up to date, numerous scientists have studied the application of plant-based extract in various products which have claimed to contain functional properties such as antibacterial (Waznah et al., 2024), antifungal (Moustafa et al., 2024), antioxidant (Ouedraogo et al. 2023), anti-inflammatory (Kiyani et al. 2023), neuroprotective (Negm and Aljarari, 2023) and anti-cancer properties (Fan et al. 2022). The

novel functional properties in plant-based extract as an antioxidant, anti-inflammatory, and anti-cancer properties have attracted the interest of scientists due to widespread of toxic effect caused by synthetic drugs (Zhou et al. 2020).

Recently, nutricosmetic has become a highlight among researchers and industry players. In general, nutricosmetic is the convergence between cosmetic and food industries. The market for nutricosmetic has a significant annual growth, since consumers are more aware on safety, nutritional, and functional products (Royer et al. 2013). Martinez et al. (2018) stated that nutricosmetic is a field comprising of food, nutrition, health, and cosmetics including products related to functional foods and nutraceuticals which brings high impact on the economic growth. Owing to the remarkable economical potential, food scientists nowadays are working toward the potential of incorporating food products into cosmetic applications. Various research has been conducted which involves dietary and nutritional component into cosmetic products. The micronutrients in the dietary and nutritional components may be benefited and improved the primary human organs including skin and hair (Taofiq et al. 2016). As seen in Figure 1, the publication on nutricosmetic is almost nil within the last 10 years which indicate very scarce research has been conducted in the related field. However, the study related to nutricosmetic is forecasted to expand year by year in parallel with its high potential and great acceptance.

Various skin care products have been marketed around the world. One of the main targets of skin care products is to combat skin pigmentation. Skin pigmentation involves multiple process, including melanin synthesis, transport, and melanosome release. Melanin content contributes to skin colour and is important for skin protection against ultraviolet radiation. However, dysregulation of melanogenesis is related to various skin diseases, including hyperpigmentation, melisma and age spots (Kim et al. 2018). The study on anti-melanogenic properties from plant-based products is important to overcome dermatological concerns causing the abnormality of excessive melanin synthesis (Lee et al. 2021).

The bioactive compounds from plant-based extract have shown various health potential (Fernandez et al. 2023). One of the well-known bioactive compounds from plants is phenolic compounds. Phenolic compounds are secondary metabolites produced from phenyl propanoic and shikimate pathways. The compounds consist of a single or more aromatic rings coupled to a single or more hydroxyl groups. The most important phenolics found in the human diet are hydroxybenzoic acid, hydroxycinnamic acids, flavonoids, and proanthocyanidins **(**Bondam et al. 2022**).**

The phenolic compounds from plant-based extract vary depending on geographical factors. Spectrophotometry, especially the Follin-Ciocalteu method, is the most widely used method for the determination of total phenolic contents and certain groups of flavonoids. This mini review examines the potential of phenolic compounds from plant extract as anti-melanogenic agent in facial mask development for the nutricosmetic industry. This review also focuses on classic and modern plant extraction methods for phenolic compounds.

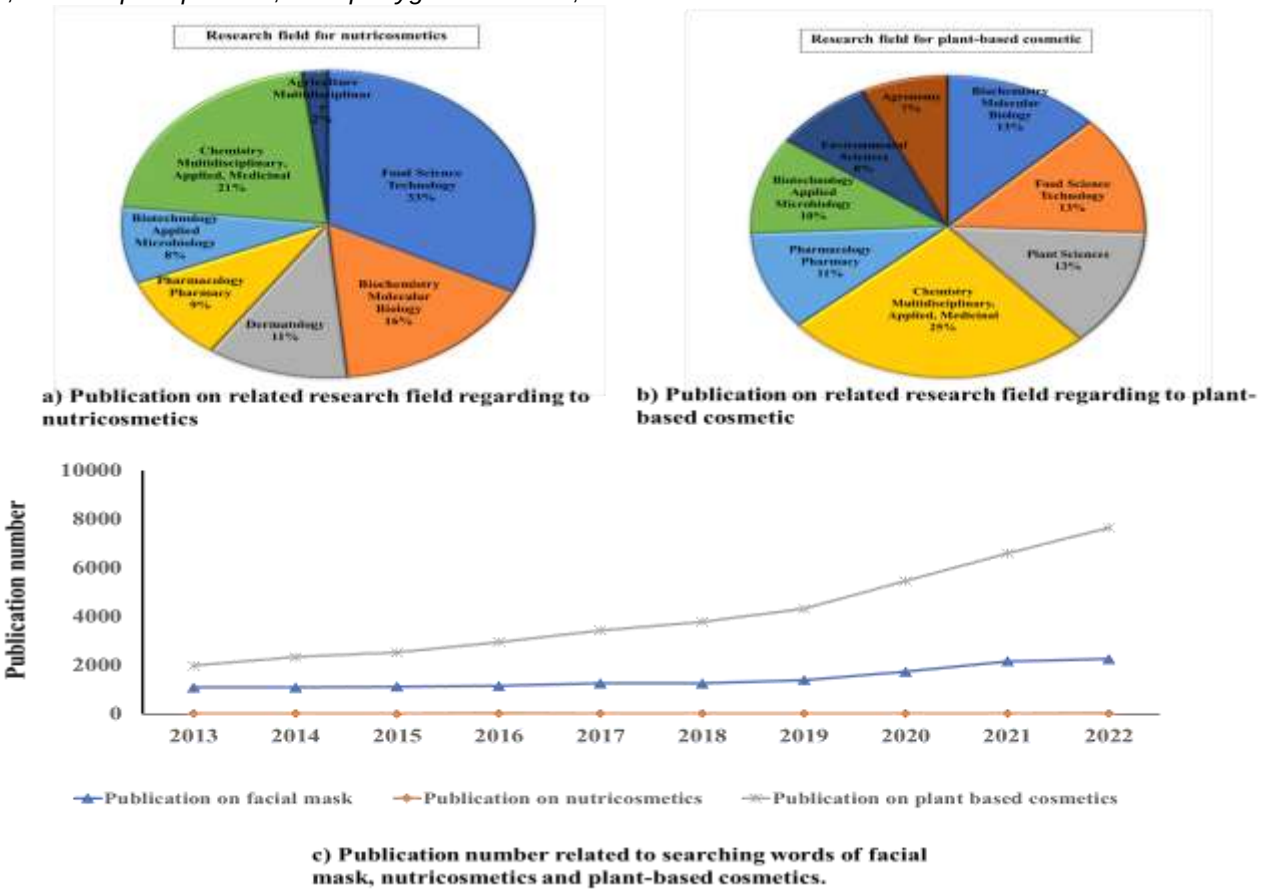
Extraction technique of phenolic compounds

Nutricosmetic products enriched with plant-based extract have gained increasing consumers attention due to their natural and safer properties. Extraction technique has normally been applied to extract the wanted compounds from the plants. Plant extraction is a process of separating soluble and important active ingredients using a solvent or combination of solvents. The plant extraction can be classified into two categories: classic extraction and modern extraction techniques.

Classic extraction technique

Classic extraction technique such as maceration, decoction hydrodistillation, Soxhlet extraction and heat reflux have long been used by our ancestors especially for the traditional herbal treatment. The most common classical extraction technique is maceration or decoction in water. This technique is the simplest technology which is easily available and can be operated without high skilled personnel. Steam distillation is also one of the classical extraction technique widely used. Chou et al. (2018) extracted *Glechoma hederacea* (Lamiaceae) using steam distillation for studying chemical composition, antioxidant, anti-melanogenic and anti-inflammatory activities. A study conducted by Ticona et al. (2022) have extracted the bark of cancerina using distillation technique. The extract was used to study wound healing, anti-inflammatory and anti-melanogenic activities. Prommaban and Chaiyana (2022) studied the microemulsion of essential oils from citrus peels and leaves using hydrodistillation for anti-aging, whitening and irritation reducing capacity. Lopez et al. (2023) studied on antioxidant-efficient indicator to determine the relationship between β-myrcene/caryophyllene (α,β) on Hop (*Humulus lupulus*) essential oil under an accelerated oxidation test. In this study, hop essential oil was extracted by steam distillation for one hour at 100 ºC. Anti-melagenic effect of the essential oil from *Citrus reticulata* blossom on B16-F10 melanoma cells and *in vivo* zebrafish embryos was conducted by Kim et al. (2023). The *C. reticulata blossom* plant was extracted by hydrodistillation with a 5 L capacity. The distillation technique to extract *Cinnamomum zeylanicum* was conducted by Tepe and Ozaslan (2020). The *C. zeylanicum* was used to study on anti-Alzheimer, anti-diabetic, skin whitening, and antioxidant activities. The product of steam distillation such as essential oils

contained valuable bioactive compositions. It is noteworthy to highlight that polar solvent such as ethanol has become the preferred choice in most solvent extraction techniques. As example, in a study conducted by Lee et al. (2019), the extraction of the aerial part of *Kummerowia striata* was conducted by solvent extraction utilizing 70% ethanol at room temperature. Meanwhile, Saad et al. (2021) studied on *Artocarpus* species for cosmeceutical applications. The plant was extracted using ethanol for three days. Ainiwaer et al. (2022) extracted *Ruta graveolens* L. using 70% ethanol. The extract was studied for melanogenic effects and their action mechanisms. Xu et al. (2022) used 80% ethanol for 15 minutes to extract *huangshui*, a byproduct of natural plant source. In a study conducted by Hsiao et al. (2023), the plant powder including *Cordyceps militaris* (Fr.) Lin, *Codonopsis pilosula*, *Notopterygium incisum*, *Polygala tenuifolia*, *Eupatorium formosanum* Hayata and others were mixed with aqueous ethanol and extracted for one day. This study was conducted to assess the skin whitening properties of the plant extract. Water as universal solvent becomes one of the most preferred solvent in classic extraction. Ranneh et al. (2021) studied on anti-aging and antioxidant of four traditional malaysian plants such as *Cnestis palala* stem, *Urceila micrantha* stem, *Marantodes pumilium* stem, and *Micropurus xanthopus* fruiting bodies. The plants were extracted by infusing in 200 mL of hot boiling water at temperature of 100 ºC. However, classic extraction techniques contributed to several disadvantages such as extraction inefficiency, degradation of thermosensitive compounds, and environmental issue.



a) Publication on related research field regarding to nutricosmetics

b) Publication on related research field regarding to plant-based cosmetic

c) Publication number related to searching words of facial mask, nutricosmetics and plant-based cosmetics.

Figure 1: Trend of published articles in ScienceDirect and Web of Science databases. a) Publication on related research field regarding to nutricosmetics. b) Publication on related research field regarding to plant-based cosmetic. c) Publication number related to searching words of facial mask, nutricosmetics, and plant-based cosmetics

Modern extraction technique

On the other hands, modern extraction techniques such as ultrasonic-assisted extraction, microwave-assisted extraction, and supercritical fluid extraction have become the alternatives for classic extraction techniques (Dias et

al. 2021). These modern extraction techniques require lesser solvent, reduces extraction time, produces high yield, focusses on green technologies concept which contribute to economic improvement and environmental sustainability. One of the most commonly used modern plant extraction technique is the ultrasound-assisted extraction. The ultrasound-assisted extraction has been frequently used in food, cosmetic, and pharmaceutical industries (Silva et al. 2023). It is an effective method to accelerate the chemical reaction by cavitation. The ultrasonic wave causes structural changes that change the internal plant matrices. The ultrasonic wave facilitates the release of targeted bioactive out from the plant matrices. In a study by Zeng and Lai (2019), fern was extracted by ultrasound-assisted extraction for 30 minutes and the extract was studied on melanoma and human skin. Supercritical fluid extraction is also widely used in many industries. However, some major limitations are dominating these methods including high cost and the equipment must be operated by skilled worker. Continued research on these advanced extraction techniques is necessary to understand the best parameters for obtaining high quality extract. In the light of these developments, numerous advanced extraction techniques have proven advantageous in obtaining remarkable plant-based extracts which minimize the used of hazardous solvents. This has attracted the development of advanced extraction methods to extract the plant sources efficiently with high quality phenolic compounds.

Phenolic compounds in plant extract and their detection methods

Plant bioactive compounds are well-known for anti-bacterial, antioxidant and anti-melanogenesis activities. One of the established bioactive compounds from plant is phenolic compounds. The phenolic compounds are frequently extracted using both the classic and modern extraction techniques. Figure 2 shows the common phenolic compounds in plant extract where extraction parameters played an important key for achieving high extraction efficiency. The mentioned bioactive compounds have been scientifically proven for its pharmacological significance and applications. The demand for a high-quality phenolic extract for health benefit has dramatically increased. According to Sanchez et al. (2016), plant polyphenols possess strong free radical scavenging properties and have exhibited the capacity to modulate multiple cellular pathways. The potential skin protective effect from plant-based extract have been reported especially to protect against solar ultraviolet (UV) radiation (Ghazi, 2022). Solar UV radiation is one of the main causes of a variety of cutaneous disorders, including photoaging, skin rashes, skin pigmentation disorders and skin cancer. A study showed that phenolic compounds such as rosmarinic acids have potential in fighting against UV radiation induced damage in human keratinocytes (Sanchez et al. 2016). In addition, phenolic compounds from plant-based have gained much attention due to the melanocyte toxicity and various adverse effects posed by the current anti-melanogenic agents The well-known anti-melanogenic agents are kojic acid, arbutin, hydroquinone, linolenic acid, and azelaic acid (Lim et al. 2022, Rahimi and Askari, 2021). Therefore, phenolic compounds from plant might be the best potential to investigate the new effective depigmenting agents with fewer adverse effects (Rahimi and Askari, 2021). Application of *Hibiscus cannabinus* L. (kenaf) leaves extract as skin whitening and anti-aging in natural cosmetic prototype was conducted by Sim and Nyam (2021). In their study, the total phenolic content and total flavonoid content were investigated. The study showed that both compounds have the potential to act as skin whitening and anti-aging agents. Recently, the study on phenolic compounds from plant have expanded their potential role in nutricosmetics. The incorporation of plant extracts in facial mask has become an interest among researchers in the field. Royer et al. (2013) have studied polyphenolic compound from Canadian forest species. The study reveals that hot water extracts are generally richer in phenolic compounds such as flavonoids compared to the ethanol extract. The study has recommended the plant extract for formulation in nutricosmetic products.

Various analytical techniques, including chromatography and spectroscopy methods have been reported for the screening, identifying, and quantifying phenolic compounds extracted from plants. Nowadays, analysis for quantification and qualification of phenolic compounds from plant-based extract has emerged as one of the important research criteria in cosmeceutical and nutricosmetic product development. A study conducted by Sanchez et al. (2016) investigated the composition in *Melissa officinalis* by high performance liquid chromatography (HPLC) analysis coupled with photodiode array detector and ion trap mass spectrometry (MS) with electrospray ionization (HPLC-DAD-ESI-IT-MS/MS). Kim et al. (2018) identified anti-melanogenic effect regulator from *Rhizoma Arisaematis* extract. The extract was analysed by Ultra-HPLC-HR and MS/MS analysis. Ticona et al. (2022) used spectrophotometric technique such as nuclear magnetic resonance (NMR) and MS to determine the composition of aqueous and sub-extract *Semialarium mexicanum* (Miers) Mennega.

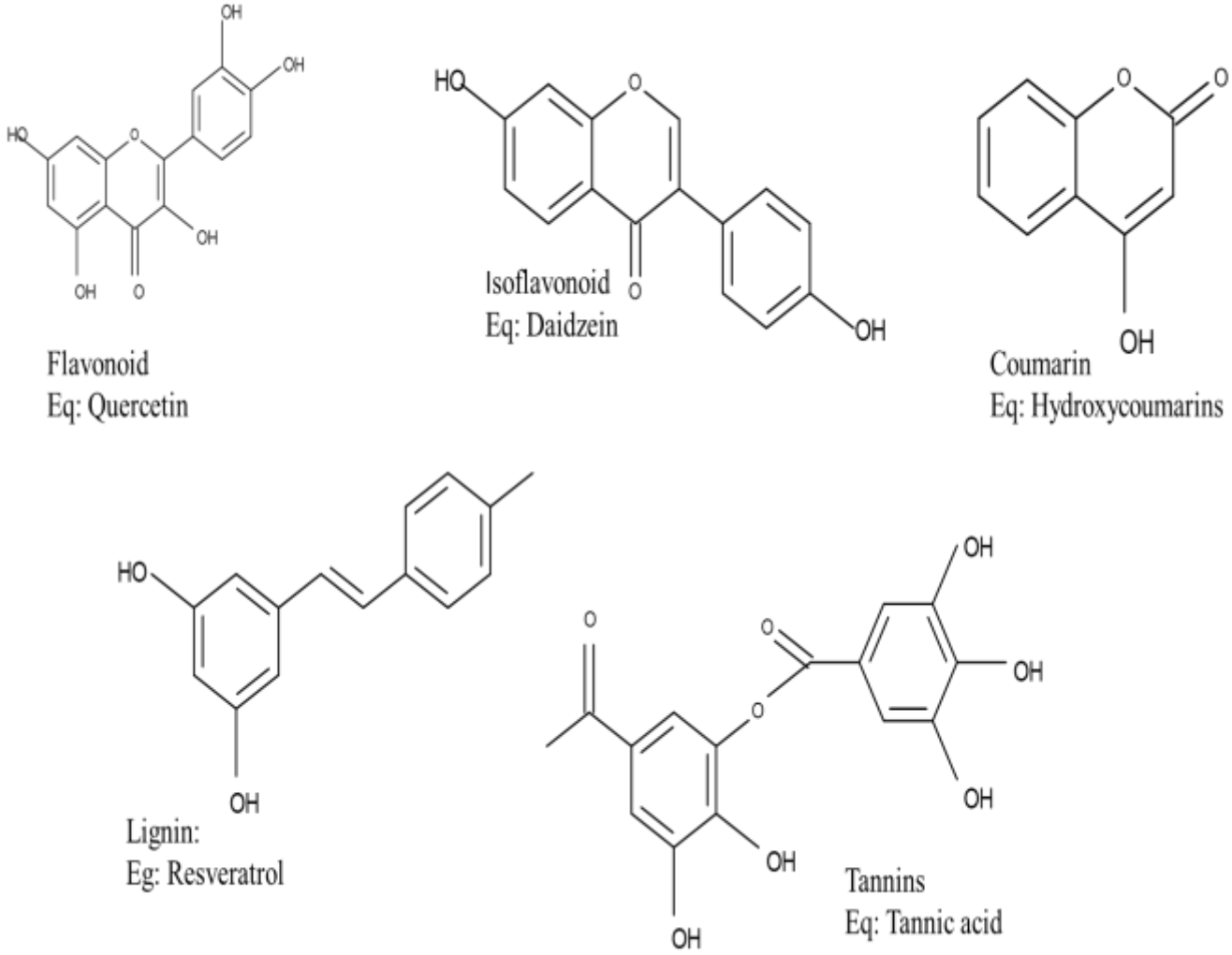


Figure 2: Common phenolic compounds in plant extract

Nutricosmetic for topical facial mask development

Skin care products has become an important product in human daily life ranging from head-to-toe products. Skin care products consist of various products such as facial cleanser, moisturiser, serum, mask and many more. The global industrial markets have recently gained high attention and demand as one of effective facial treatment as anti-melanogenic agent for combating the extensive melanin production which may contribute to accumulation in skin which effect skin discoloration (Hatem et al. 2020). Melanin is multifunctional biopolymer inside the skin which has many crucial physiological functions, including skin protection from the exposure towards UV radiation-induced damage. However, overproduction and accumulation of melanin can result in darkening of the skin and/or skin diseases, including freckles, chloasma, pigmentation, post-inflammatory melanosis, and solar lentigo (Zhang et al. 2020). Better understanding on the mechanisms of melanogenesis may help to find a proper solution for skin diseases and pigmentation dysregulation which might facilitate the development of potential cosmetic product (Kim et al. 2028).

Anti-melanogenic properties

Plant-based extract has been selected as one of the key ingredients in developing new facial skin care products. Various studies have been conducted to investigate the potential of plant resources especially as anti-melanogenic properties. A study was conducted by Ainiwaer et al. (2022) on chemical constituent of *Ruta graveolens* L. and their melanogenic effects and action mechanism. The study confirmed traditional efficacy of *R. graveolens* has potential in melanogenic effects. Zeng and Lai (2019) studied on anti-melanization effect using edible fronds of *Aplenium australasicum*, a popular fern vegetable in Taiwan. Anti-melanogenic effect from *Kummeerowia striata* was investigated by Lee et al. (2019). *K. striata* is an annual plant indigenous to East Asia, including Korea, China, and Japan. This plant has long been used in traditional medicine. The study revealed that *p*-coumaric acid and quercetin from *K.*

striata are important compounds for anti-melanogenesis. The study suggested the development of *K. striata* as functional supplement in cosmetic which may be useful for skin whitening and reducing wrinkle. Wang et al. (2022) have studied on anti-melanogenic effect from extract of *Glycyrrhiza glabra L.* The study exhibited the potential of *G. glabra* on enhancing the anti-melanogenic effect. Chatatikun et al. (2019) studied anti-melanogenic effect on *Croton roxburghii* and *Croton sublyratus* which belong to the Euphorbiceae family. The plants are popular in traditional medicine to treat ringworm, wounds, scabies, skin diseases, liver diseases, diarrhoea, fever, and headache. The finding from the study reveals that both *C. roxburghii* and *C. sublyratus* have potential to inhibit melanin content and cellular tyrosinase activity through suppressing microphthalmia-associated transcription factor (MITF) and melanogenic enzymes. *C. roxburghii* and *C. sublyratus* is suggested to be combined with other skin whitening agents in cosmetic products for their synergistic effects. The effect of polyherbal Unani formulation incorporating extracts from *Psoralea corylifolia, Punica granatum, Zingiber officinale, Eclipta Alba,* and *Terminalia chebula* on melanogenesis was studied by Ghali et al. (2022). The study revealed that plant bioactive compounds play major role in combating diverse hypopigmentation effect. Lim et al. (2022) studied the potent melanogenesis inhibition by friedelin isolated from *Hibiscus tiliaceus* leaves. *H. tiliaceus* commonly found at the shorelines of Southeast Asia has been used in traditional treatment to treat fevers and coughs and are also wrapped around bone fractures to fasten the treatment. In this study, *H. tiliaceus* has been proved to contain friedelin as the main compound which is responsible to inhibit tyrosinase *in vitro* and melanogenesis in cells. Friedelin has the potential to be formulated into a tropical skin whitening product. Apart from that, Sepehri et al. (2021) have studied on melanogenesis pathway. A series of kojyl thioether conjugated to different quinazolinone derivatives were designed, synthesized, and evaluated for inhibitory activity as measured mushroom tyrosinase inhibition assay protocol. The tyrosinase enzyme plays important roles in signalling pathway in melanogenesis. Zhou et al. (2020) studied on anti-melanogenesis effect of essential oils extracted from *Dalbergia pinnata* (Lour.) Prain. *D. pinnata* is a plant widely distributed in tropical and subtropical regions of Asia, Africa, and the Americas. This plant is commonly used in prevention and treatment of diseases such as respiratory systems, digestive system, cardiovascular and cerebrovascular disease. In this study, *D. pinnata* showed potent inhibitory impacts of the extracted essential oil towards skin pigmentation. Woo et al. (2019) have tested *Premna serratifolia* woods against melanogenesis. The study showed that *P. serratifolia* have the possibility as anti-melanogenesis without any cytotoxicity effects. It can be concluded that, plant-based extracts have huge potential for anti-melanogenesis and could be applied in the development of nutricosmetics products.

Revolution of facial mask ingredients

Facial topical mask is now becoming one of the highly demanded skincare routines. Plant-based origins are widely used as biologically active substance in pharmaceutical and cosmetic industry, substituting plant vegetative parts with callus cell extracts (Chalageri et al. 2019). A study conducted by Xu et al. (2022) has prepared and characterized electrospun nanofibers-based facial mask containing hyaluronic acid and other bioactive compounds as antioxidant compounds. The study found that the combination between electrospinning and *Baijiu huandshui* as bioactive compounds have potential in providing antioxidant activity. According to the study, most of the facial mask sheets are soaked in liquids with addition of various essence ingredients especially from plant extract. Since the COVID-19 pandemic, majority of the researchers focus on developing various skin care products that can protect human against the virus and other pathogens. Bamgbade et al. (2022) investigated how facial topical cream promote facemask tolerability and compliance.

Other emerging research revolution is the combination of biodegradable antioxidant chitosan films for anti-aging skin mask. The study was conducted by Afonso et al. (2019) to utilise the bio-based polymers as ingredient in cosmetics, personal care, and biomedical products. The growing market on bio-based polymers might be due to the ecological awareness that have changed the consumers demands, causing consumers to look for more sustainable options, with lower environmental impact. The innovation of the previous work was to develop a natural polymer matrix entrapping antioxidant compounds which could be a great platform for face mask sheet development.

Challenges and future prospect of plant-based nutricosmetic

The application of food products into cosmetic products are important for future prospect in nutricosmetic which can expend further both the food and cosmetic industries. The cosmetic products such as facial mask might be in lathering form and non-lathering or emollient. The lathering form is liquids, gels, and scrubs. Non-lathering or emollient form is cream and lotion (Loretz et al. 2008). One of the main challenges when incorporating plant-based extract as food and cosmetic resources is product stability. Stability studies include the study on physical, chemical, and microbial characteristics are necessary for nutricosmetic formulations. The formulation type, intent of use and potential interaction between the ingredient used in the formulation which contribute to stability and safety are among the important consideration for product development (Sim and Nyam, 2021).

Other challenges and future prospect for nutricosmetic is the potential of environment pollution due to the contamination of microplastic from personal care and cosmetics products. It was highlighted that a total of 199 million microplastics were estimated to be emitted from personal care and cosmetic products into the marine environment (Praveena et al. 2018). Until now, there is no permanent effective removal method to eliminate these micro-sized particles once they have been emitted (Praveena et al. 2018). Therefore, combination between plant and food resources is one of the solutions to replace the microplastics ingredients and eventually can mitigate the microplastic contamination.

Activated charcoal as face whitening

In our daily routine, facial skin products for moisturizing, whitening and sun protection have become an important role in human wellness. Various ingredients are added to the facial skin products including topical facial mask. One of the popular ingredients is activated charcoal. Biochar and activated charcoal are popular nowadays due to the advantageous in assisting the adsorption of excess oil from the skin, digestion and nutrient absorption. The charcoal was proven effective in supplementing poultry diet (Farghly et al. 2023), gastric decontamination (Jumaan et al. 2023) and to treat intoxication (Zellner et al. 2019). Therefore, new strategies can be executed in utilising charcoal in nutricosmetics. The biochar from plant resources has a great economic potential as they contain various phytochemical that showed various functional potentials. According to Tomas et al (2023), whitening is one of the potential effects using charcoal. There has been a rising understanding of the value of biochar applications. However, the challenge for the application of activated charcoal arises when it comes to product development. More study and quality research are needed to utilise activated charcoal (Tomas et al. 2023). Activated charcoal is generally safe, though it is not recommended for chronic oral intake (Sanchez et al. 2020). Further extensive study is still needed especially to determine the efficacy and safety of nutricosmetic products with the activated charcoal.

Fruits for skin radiant

Fruits are well-known for providing essential nutrients to human body which contribute to collagens synthesis. The skin is a tissue with high metabolic activity. The skin plays an important role as protective layer (Cano et al. 2021). Therefore, long-exposed skin tissue towards UV rays contribute to skin dullness. Collagen synthesis maybe one of the solutions for enhancing skin radiance. Consuming natural resources such as fruits is important for skin radiant. The nutrients inside fruits act as catalyst within living cell. The fruits are scientifically proven to contain high antioxidant agents that may help in maintaining youthful looking skin. The popular fruits for skin radiant are papaya, pineapple, fig, mulberry, and soyabean. It might be due to papaya containing enzymes which shows the potential of skin enhancer. Most common enzymes from papaya are papain (Trevisol et al. 2023), bromelain from pineapple, ficain from fig and lipoxygenase from soyabean. A study conducted by Cho et al. (2018) has reported the effect of fruits stem extract from *Muscat Bailey* A against chronic UV-induced skin damage. This study is significant in understanding how the ultraviolet-B (UVB) radiation, which has become the primary source of oxidative stress, affects humans. Another study conducted by Zhang et al. (2023) revealed that mulberry exhibited anti-skin aging effect. The *in vitro* study showed positive impact on methylglyoxal-bovine serum albumin (MGO-BSA) models in the fructose-BSA. The study also revealed that phenolic contents from the compositional analysis carried out positively correlated with antioxidant capacity which can potentially reduce the oxidative stress damage and thus, enhancing anti-aging effects.

CONCLUSIONS

Plant-based extracts containing phenolic compounds have shown to be a promising ingredient for developing bioactive compound enriched facial mask, particularly within the nutricosmetic industry. To fulfil the growing interest of consumers' demand for nutricosmetic product, various extraction methods have been explored based on the extraction efficiency and performance of the bioactive compounds. Aligned with increasing consumer awareness, natural products, especially those derived from plant-based sources are recognized to have all the potential strategies for developing facial mask with nutricosmetic properties. Numerous studies have proven that plant-based extract have good anti-melanogenic properties. Future research endeavours may focus on novel approaches such as combining plant-based phenolic compounds with other bioactive such as activated charcoal and fruit nutrients for a synergistic benefit, paving the path advancements in the field of nutricosmetics.

Supplementary materials

The supplementary material / supporting for this article can be found online and downloaded at: https://www.isisn.org/article/

Author contributions

All authors contributed to the study. Investigation, conceptualization, resources, visualization, writing and editing were prepared by Ida Madiha Yusoff. Siti Pauliena Mohd Bohari, Widya Fatriasari, Zehra Edis read and approved the manuscript. Funding acquisition, conceptualization, writing and editing were provided by Nur Izyan Wan Azelee.

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All the data is included in the article

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Conflict of interest
The authors declared that present study was performed in absence of any conflict of interest.

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